Nutrient management in effluents derived from agricultural industries: an Australian perspective

R. Matheyarasu[1,2], B. Seshadri[1,2], N. S. Bolan[1,2] & R. Naidu[1,2]
[1]*CERAR – Centre for Environmental Risk Assessment and Remediation, University of South Australia, Australia*
[2]*CRC CARE – CRC for Contamination Assessment and Remediation of the Environment, University of South Australia, Australia*

Abstract

The effluents derived from agricultural industries are major sources of wastewater with significant amounts of nutrients and organic load. Australia's agricultural industries have experienced rapid growth in recent years, with nearly 152 abattoirs, 1798 wine industries, 9256 dairy farms and 1835 piggeries in operation. Agricultural industries require huge volumes of water for processing the farm products towards commercial value and quality. For instance, around 200 L of water required for processing a cattle in an abattoir; around 2.4-2.5 L for producing 1 L of wine; 500-800 L for 1 L of milk; and 12-45 L for sow and litter management in piggeries. As a result, these industries generate huge volumes of wastewater. For example, Australian meat industries produce an average of 4000 m^3/day wastewater, with high concentration of nitrogen (N) and phosphorus (P). The annual average N and P loads in some of the farm effluents are: abattoir – 722 and 722 t; winery – 280 and 280 t; dairy – 150000 and 110000 t; and piggery – 72895 and 5075t. With Australia's average fertiliser consumption being 1 Mt N and 0.5 Mt P, the huge amounts of N and P from the agricultural effluents can be re-used as a potential alternative for fertiliser usage. Sustainable management of nutrients in the wastewater irrigated soil is a critical step to prevent contamination of both surface and ground-water. The available technologies for wastewater treatment require high investment. Hence, using high biomass-producing plants (e.g., *Pennisetum purpureum* and *Arundo donax*) as remediators, which also has the potential to uptake high amount of nutrients and heavy metals, can serve as a cost effective technology. Consequently, the

degradation, accumulation of toxic metals in plants and animals. For instance, the production of meat, milk and wine results in the generation of wastewater with a significant amount of pollutants, nutrients and pathogens. Moreover, these agricultural industries are also responsible for global warming and climate change. To overcome the above problems caused by the agricultural industries, sustainable alternative methods are needed which will not only reduce the pressure on global fresh water resources, but will also help in meeting the demands of water for households, industries, agriculture, and environment.

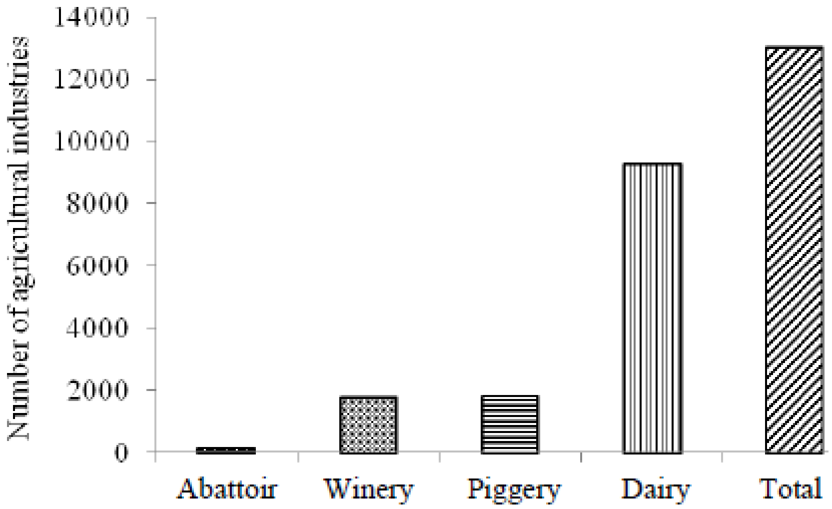

Figure 2: Number of agricultural industries in Australia.

2 Water use in agricultural industries and wastewater generation

The Agricultural industries consume water for processing to the level of commercial requirements; abattoirs need huge quantity of water for processing meats (cooling, cleaning and rinsing), operating utilities (boilers, cooling towers and pumps) and for ancillary uses such as toilets and washing facilities, thereby discharging large quantity of wastewater [8]. A typical abattoir uses about 15000 litres mainly to clean the floors and walls of the slaughter house [9]. On an average, 200 L of water is required for processing a cattle in abattoirs [10]. A three year study by Meat Livestock Australia (2010) found that 10 kL/tHSCW of clean water is consumed and equally discharged in a meat processing industry.

Among the agricultural industries, dairy farming is one of the major sectors in Australia. Dairy farming is the second largest water consumer after irrigated agriculture [7]. Nearly 500–800 L of water is required for producing 1 L of milk; the dairy industry needs 1 ML of irrigation water to produce 2000 L of milk [7]. National milk production intensity increased from 2750 L (1980) to 5163L (2006) per cow per annum [7, 11]. The increased milk production is being achieved by an increased amount of inputs (fertiliser, feed or nutrient rich

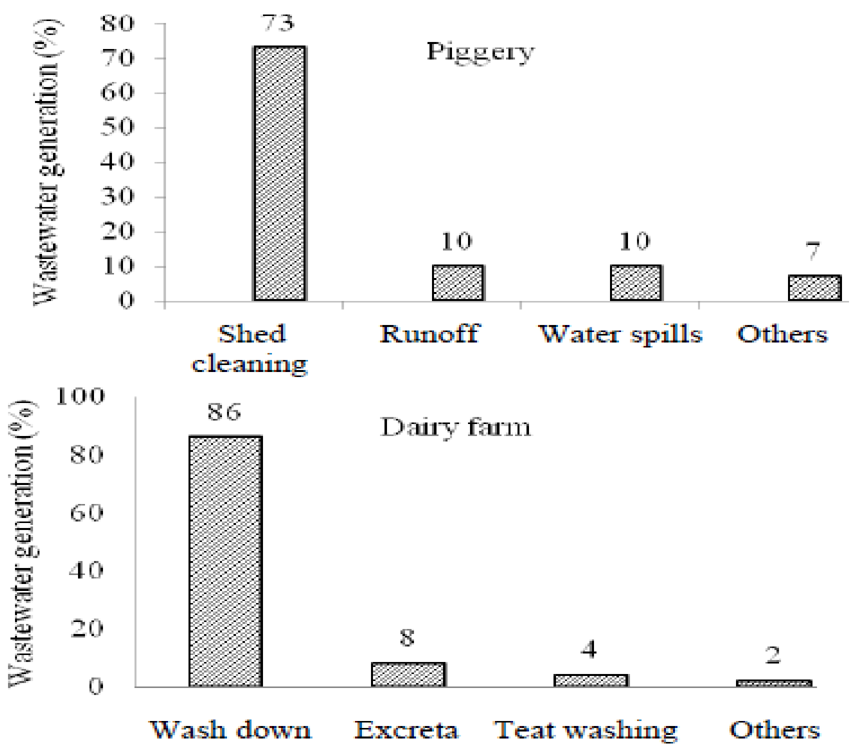

Figure 3: Continued.

3 The nature of agricultural industries wastewater

Abattoir wastewater is a rich source of nutrients; even after primary treatments, resulting in high cost for further treatment and disposal [14]. Abattoir wastewater derives organic loads from different sources. Animal manure contributes significant amount of pollutants to the abattoir effluent containing N, P, and organic carbon [4]. In comparison with other wastewater sources, abattoir wastewater stream possess the highest concentration of organic load, with increased COD (8000 mg/L), proteins (70%) and suspended solids (15–30 mg/L) [15].

Piggery effluent contains 158-1025 mg/L of N; 11-123 mg/L of P; 97–1845 mg/L of K and 103—2870 mg/L of Na with other beneficial micro nutrients [9, 16]. According to the APL-AMIC –projects report, water usage, feed grain supply and managing nutrients in the piggery effluents are the major environmental challenges faced by Australian piggeries [9]. Piggery effluents and by-products can be used as valuable alternatives for fertiliser for agricultural

integrated method of nutrients management in abattoir wastewater is the best approach, where the combination of aerobic and anaerobic processes is important in a biological treatment process. Del Pozo and Diez [21] found 93% and 67% of organic load N removal efficiency, respectively by an integrated aerobic-anaerobic film reactor. Increased level of wastewater generation requires highly efficient and cost effective methods for the continuous removal of N and P [20]. Nitrogen from wastewater can be removed by ammonia stripping, which is relatively a high cost technology to reduce N-concentration in wastewater.

The above mentioned approaches are generally expensive to operate in terms of initial establishment and maintenance. The use of plants to remove excess nutrients and also to produce biomass will be a cost-efficient approach to utilise the wastewater resources. For example, the nutrients in the wastewater can be utilised by plants. However it purely depends on types of soil and plants species used.

Land disposal of waste and wastewater is most common practice of waste disposal by Australian piggeries. Majority of the piggeries (78%) have the wastewater treatment pond. Among these 83% has multiple pond system to treat the effluents [12]. High biomass yielding plant species such as sorghum and maize silage can suitable crops for land treatment of wastewater because of its ability to remove significant amount of nutrients [9].

Dairy farm wastewater is commonly treated with two stage pond systems – aerobic and anaerobic ponds, which are effective only for removing organic load (BOD) and sediments but not effective for N and P removal [22]. The land treatment of dairy effluent with high nutrient uptake or biomass producing plant is most suitable method of managing wastewater and the biomass produced from these plants (i.e., *Salix kimuyanagi*) can be used as a feed for animals [17].

5 Phytoremediation/low - cost technology

Agricultural industries require an additional capital to treat and discharge of effluent. This will be a major limiting factor for the small and medium scale industries. Phytoremediation of contaminated soil irrigated with effluent from agriculture industries by high biomass producing plant species is a cost effective techniques to reduce the risk of nutrients and bioorganic compounds reaching aquatic environment [17]. It is most essential that industries need to adopt various best practices/low cost technologies to reduce their water use and cost. Irrigation of wastewater is a potential low-cost approach of wastewater management and can act as a good source of nutrients for infertile soils [25, 26]. Australia, with several meat based industries need to manage the animal wastes and effluents using low cost technologies [4, 12]. The amount of organic load, N and P, and organic carbon concentration can be reduced by prior collection of manure before wash down, which will reduce effluent loading with high concentration of pollutants [25]. Abattoir wastewater is a richest source of N and P; hence it can be treated as an alternative source of nutrients provider for low fertile soils [26]. Using high biomass-producing plants (e.g. *Pennisetum purpureum* and *Arundo donax*) as remediators, which also has the potential to

uptake high amount of nutrients and heavy metals, can serve as a cost effective technology. The brief details about nutrient uptake and biomass yielding capacity of selected plant species are listed in the Table 3.

Table 3: List of high yielding, high nutrient up-take plans species [9, 25].

Crops	Biomass yield Mg/ha	Nutrient uptake kg/ha		
		N	P	K
Napier	10–40	150	30–70	375–450
Giant reed	45	528	22	664
Sunflower	10	200	35	450
Lucerne	25	150–450	15–45	554
Maize silage	10–25	220–550	30–75	200–500
Fodder sorghum	15	200–400	35–75	332
Cereal	2–6	59–239	9–20	–
Dryland pasture	1–4	20–80	3–12	15–60
Irrigated pasture	8–20	16–400	24–60	120–300
Grain sorghum	2–8	40–160	6–24	–
Cotton	2–5	40–100	8–20	16–40
Chick pea	0.5–2	20–80	2–8	2–8
Cow pea	0.5–2	15–60	2–8	10–40

6 Conclusion

Wastewater reuse after removing the pollutants, nutrients and pathogens is an important component in the sustainable management of water resources and ensuring water security. Phytoremediation of abattoir wastewater treated soils can emerge as a sustainable measure towards water resources management. Phytoremediation is energy efficient, aesthetically pleasing method of remediating sites with low to moderate levels of contamination and it can be used in combination with other more traditional methods such as multiple ponds, wetlands. The remediation of wastewater irrigated soil using specific plant species such as *Pennisetum purpureum* and *Arundo donax* as remediators, which also has the potential to uptake high amount of nutrients and heavy metals, can serve as a cost effective technology. Consequently, the plants used not only act as remediators, but also provide biomass that can also be used for energy generation, paper production and as a feed for animals.

Acknowledgement

We would like to thank CRC CARE for providing funding (No 4.2.1.11/12) to undertake research on nutrient management in wastewater discharged soil.

References

[1] UN WWAP, The United Nations World Water Assessment Programme, 'The World Water Development Report 1: Water for People, Water for Life', http://webworld.unesco.org/water/wwap/panels/colors/montage.pdf. 2003.

[2] Australian and New Zealand Environment Conservation Council (ANZECC), 'Australian guidelines for the sewage systems effluent management', National water quality management strategy, pp. 1-20, 1997.

[3] Australian Bureau of Statistics, 'Water Account for Australia,' http://www.abs.gov.au, 2011.

[4] MLA, 'Nitrogen management strategy for meat processing plants', pp. 2-50, August 2003.

[5] Australian Bureau of Agricultural and Resource Economics and Sciences (ABARES), *Agricultural Commodities*, pp .1-225, 2012.

[6] Kumar, A., Arienzo, M., Quayle, W., Christen, E., Grocke, S., Fattore, A., Doan, H., Gonzago, D., Zandonna, R and Bartrop, K., 'Developing a systematic approach to winery wastewater management', Report CSL05/02. Final report to Grape and Wine Research and Development Corporation (CSIRO Land and Water Science Report Adelaide), 2009.

[7] Dairy Australia, http://www.dairyaustralia.com.au/.

[8] Cristian, O., 'Wastewater quality monitoring in meat industry', Analele Universităţii din Oradea, Fascicula: *Protecţia Mediului*, pp. 715-718. 2010.

[9] Australian Pork Limited (APL), National Environmental guidelines for piggeries, second edition, pp. 1-97, 2010.

[10] Emeka, U.J., Braide, S.A., and Chindah, A.C., 'Impact of abattoir wastes based on some physicochemical parameters on Woji Creek, Port Harcourt, Nigeria', *Management of Environmental Quality: An International Journal*, pp. 581-591, 2009.

[11] Gourley, C., Powell, J., Dougherty, W and Weaver, D., 'Nutrient budgeting as an approach to improving nutrient management on Australian dairy farms'. pp. 1065-1072, 2007.

[12] Australian Meat Processor Corporation, (AMPC) http://www.ampc.com.au/

[13] Hoekstra, A.Y., and Chapagain, A.K., 'Water footprints of nations: water use by people as a function of their consumption pattern', *Water Resources Management*, pp. 35-48, 2007.

[14] Li, C.T., Wu, C.S., and Huang, J.S., 'Chemical/Bio-fluidized Bed Treatment of Slaughterhouse Wastewater', *Journal of Environmental Engineering*, pp. 718, 1986.

[15] Ruiz, I., Veiga, M., De Santiago, P and Blazquez, R., 'Treatment of slaughterhouse wastewater in a UASB reactor and an anaerobic filter', *Bioresource Technology*, pp. 251-258, 1997.
[16] EPA-SA, 'Guidelines for the site contamination audit system', pp. 1-17 http://www.epa.sa.gov.au/.2009.
[17] Marmiroli, M., Robinson, B.H., Clothier, B.E., Bolan, N.S., Marmiroli, N and Schulin, R., 'Effect of dairy effluent on the biomass, transpiration, and elemental composition of *Salix kimuyanagi*', *Biomass and Bioenergy*, 2011.
[18] Massé, D and Massé, L., 'Characterization of wastewater from hog slaughterhouses in Eastern Canada and evaluation of their in-plant wastewater treatment systems', *Canadian Agricultural Engineering*, pp. 139-146, 2000.
[19] Mittal, G.S., 2006, 'Treatment of wastewater from abattoirs before land application – a review', Bioresource Technology, pp. 1119-1135, 2006.
[20] Yilmaz, G., Lemaire, R., Keller, J and Yuan, Z., 'Simultaneous nitrification, denitrification, and phosphorus removal from nutrient-rich industrial wastewater using granular sludge', *Biotechnology and Bioengineering*, pp. 529-541, 2008.
[21] Del Pozo, R., and Diez, V., 'Integrated anaerobic-aerobic fixed-film reactor for slaughterhouse wastewater treatment', Water Research, pp. 1114-1122, 2005.
[22] Bolan, N.S., Laurenson, S., Luo, J and Sukias, J., 'Integrated treatment of farm effluents in New Zealand's dairy operations', *Bioresource Technology*, pp. 5490-5497, 2009.
[23] Johns, M., 'Developments in wastewater treatment in the meat processing industry: A review', *Bioresource Technology*, pp. 203-216, 1995.
[24] Husband, P., 1992, 'The meat industry and the environment-changing regulatory position', MEAT' 93, The Australian meat industry research conference, pp. 1-7, 1993.
[25] Reuter D.J., and Robinson J.B., (eds). Plant Analysis – An Interpretation Manual. CSIRO Publishing, Collingwood, Victoria, 1997.
[26] Rivera, F., Warren, A., Curds, C.R., Robles, E., Gutierrez, A., Gallegos, E., Calderon, A., The application of the root zone method for the treatment and reuse of high- strength abattoir waste in Mexico. *Water Science Technology*, pp. 271-278, 1997.